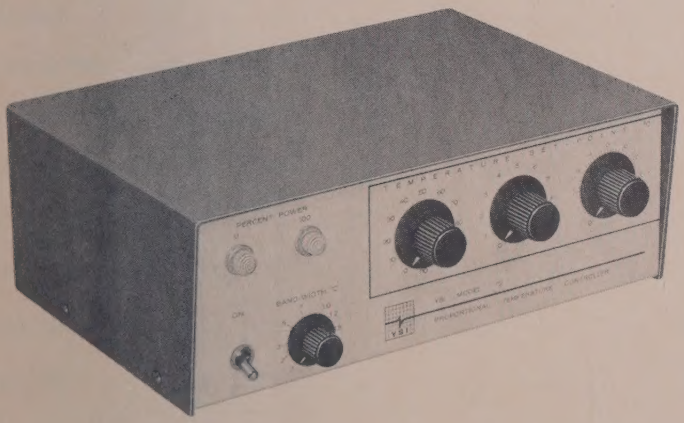
INSTRUCTION MANUAL
YSI MODEL 72
PROPORTIONAL CONTROLLER



Scientific Division

Yellow Springs Instrument Co., Yellow Springs, Ohio 45387

PRICE $5.00

INSTRUCTION BOOK
YSI MODEL 72 PROPORTIONAL CONTROLLER

TABLE OF CONTENTS

Page

230 VOLT 50 Hz INFORMATION 1

GENERAL DESCRIPTION 2

SPECIFICATIONS 2

OPERATING INSTRUCTIONS 3

- Installation 3
- Operating Parameters 3
- Thermal System Consideration 4
- Load Considerations 6
- Bandwidth Admustments 7
- Temperature Adjustments 7

CALIBRATION 8

GUARANTEE 8

SCHEMATIC ..... CENTER SPREAD

230 VOLT INFORMATION

If this instrument has been purchased as a 230 Volt Model, the following notes should apply to statements made in the instructions.

1. 230 Volt Operable from 190-250 VAC.
2. Wattage: Up to 2 KW RESISTIVE load may be controlled with 230 Volt Model.
3. The Schematic contains notes indicating changes which have been made to the circuit.

MODEL 72 PROPORTIONAL CONTROLLER

GENERAL DESCRIPTION

The Model 72 Proportional Temperature Controller is a precision solid state electronic controller capable of maintaining temperatures with a constancy far exceeding that of on-off type controllers. The instrument is provided with a direct dialing system which enables the user to select the desired control point directly in degrees Centigrade. The use of solid state circuitry throughout results in very high reliability of the instruments.

The temperature is sensed by means of a thermistor probe which forms one leg of a modified alternating current Wheatstone bridge. The output of the bridge is an a.c. error signal whose amplitude is proportional to the temperature deviation of the probe from the selected temperature, and whose phase determines the direction of this deviation. This signal is amplified by means of a stabilized amplifier to an amplitude corresponding to a voltage gain of about 1000. The amplified signal is demodulated, by means of a phase sensitive detector, so that a d.c. output appears whenever the phase of the error signal indicates that the temperature of the probe has exceeded the selected control point. The d.c. signal is fed to a firing circuit which controls the conduction angle of a Triac so that a continuously variable power is fed to the heater. Because of the linear nature of the intervening circuits, the power to the heater can be varied smoothly, and is an inverse function of the temperature rise above the set point. In a control situation the controlled temperature differs from the selected temperature only by a small error signal which is a function of the thermal losses of the controlled medium. Once control has been established, any disturbance of the controlled medium will be sensed by the probe and the controller will immediately furnish corrective action by supplying or withholding heat to the medium at the rate required to maintain the controlled temperature constant.

The bridge of the instrument is supplied from a variable alternating current source which is manually adjustable from the front panel of the instrument. By means of this control the sensitivity or bandwidth may be varied to render the instrument compatible with a wide variety of control applications. The bandwidth is presented in degrees Centigrade and represents the temperature band within which the instrument is performing its intended function. If, for example, the bandwidth control is set at 0.1°C, the controller output will vary from 0 to 100% power for a 0.1°C drop of the sensed temperature.

SPECIFICATIONS

Direct Dialing: Any control temperature between 0°C and 120°C may be directly selected to an accuracy of ±0.5°C.

Setability: Within ±0.005°C by using last selector dial as vernier.

Controlled Medium Stability: The controlled temperature point may be maintained to within less than ±0.01°C in well designed control systems. (See

Thermal Systems Consideration)

Instrument Stability: (bandwidth set at 0.1°C) — The instrument control point will be maintained to within ±0.02°C for an ambient temperature change of ±10°C and/or a line voltage variation of ±10%.

Bandwidth: The proportioning band, hereafter referred to as the "bandwidth" is nominally variable from less than 0.1°C to approximately 3°C. (See Operation)

Power Output: 117V AC resistive heater loads of up to 1.1 KW (230 VAC, up to 2.2 KW) may be controlled by the instrument. A slide switch is located inside the instrument intended for use with low voltage heaters. (See Operation and Load Considerations)

Power Requirements: 117 VAC, 50/60 Hz. Up to approximately 1.1 KW power (up to 2.2 KW for 230 VAC) may be required depending upon the heater. The instrument is operable with line voltage variations from 100 to 135 volts.

Fuse: The instrument is protected by a fast acting fuse type KAX 10A manufactured by Bussman Manufacturing Division, McGraw Edison Company. One replacement is included in the instrument. Only exact replacements should be used.

Ambient Temperature: The instrument is operable within an ambient temperature range of 0° to 50°C.

Temperature Probes: The instrument is designed for operation with YSI Series 400 Thermistor Temperature Probes (See YSI Probe Catalog).

OPERATING INSTRUCTIONS

Installation

The Model 72 may be installed where a convenient 117V 10 amp 50 or 60 HZ alternating current is available. For optimum performance and maximum safety the instrument should be supplied from a three-way socket which effectively grounds the instrument chassis. If a three-way socket is not available, an adapter may be used, but it is recommended that the instrument be well grounded through the adapter ground spade lug.

The Model 72 has been specifically designed for operation with YSI 400 series interchangeable thermistor probes which make possible the direct dialing feature of the instrument. The thermistor probe and the heater are connected to the instrument by suitable outlets on the back panel. The probe is simply plugged into the phone jack, and the heater connection may be made through a 3-way or 2-way standard a.c. plug. The triac is mounted to a heatsink inside the instrument. Because the Triac dissipates heat in operation it is important to place the Model 72 in a location that allows free air circulation for cooling.

Operating Parameters

The need for proportional type of temperature control arises in control systems where the temperature cycling of on-off controls can not be tolerated. The inherent property of proportional control is its ability to supply power to the heater which is continuously proportional to the temperature deviation from the set

point. Because of the absence of discontinuities around the set point, the controlled temperature may be held constant with negligible temperature cycling.

The adjustable bandwidth and fast response time features render the Model 72 applicable to almost any control situation, provided certain control criteria are observed. The control criteria are discussed below with particular reference to the various elements necessary in putting together a temperature control installation. With the proper design of the entire system, control stabilities of much better than +10°C are possible.

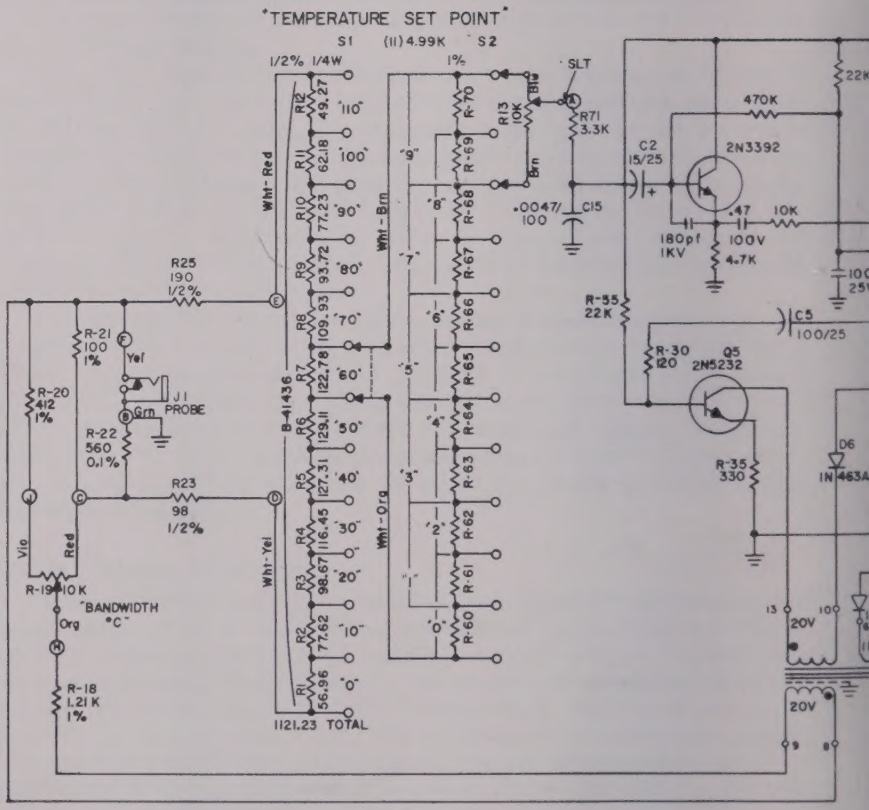
It should be noted what difficulties can arise when a failure occurs. If there is a power interruption the system turns off since the controller gets power from the same source as the heater. If a component in the controller fails the system can either turn completely on or off, depending on which component fails. Thus some component failures could cause the medium being controlled to grossly overheat. To protect against this an inexpensive bi-metal switch or similar device should be used in series with the heater or the controller for unattended operations. Merely set the switching temperature of the bi-metal a few degrees higher than the control temperature.

It is recommended that when selecting a probe, reference be made to the YSI Thermistor Probes Catalog which gives detailed specifications on all 400 Series probes. The time constant of the probe is an important consideration, particularly where close control is required. Fast probes tend to speed up overall system response and enable the operator to achieve good stability with narrow bandwidths. The proper selection of suitable probe for critical applications is also in part dependent upon the setting of the bandwidth control. (See Bandwidth Adjustments)

Thermal System Consideration

To achieve the full control performance of which Model 72 is capable requires careful design of the entire thermal system of which the controller is a component. For closest control it may be necessary to control ambient temperature at the location of the controller. Changes in the temperature represented by the dial settings will be not more than ±0.02°C for ambient temperature changes of ±10°C. For closest control it may also be necessary to regulate line voltage. Changes in the temperature represented by the dial settings will be not more than ±0.02°C for line voltage variations from 100 to 135 volts a-c with the bandwidth set at 0.1°C. Changes occurring in the thermal load of the system or sudden changes in line voltage represent disturbances of the thermal system equilibrium. The speed with which these disturbances can be sensed and corrected for through the thermal inertia of the system largely determines control stability. Model 72 controllers contribute a time lag of approximately 0.1 second, which is usually negligible compared to the time constants of other portions of the system.

Probe location is an important consideration in system response time. In locating the probe with respect to the rest of the system, it must be kept in mind that the purpose of the probe is to sense the temperature changes imparted to



NOTE:

1. All resistor values are ohms: K=1,000; M=1,000,000. Resistors are 1/2W, 10% unless otherwise specified.
2. All capacitors values are in microfarads/voltage.
3. On 230 Volt - 2 each 10C7 in series.
4. 230 Volt 50-60 Hz
5. SC50D triac for 230V.
6. "X" denotes break for connection of 230V, Wire per doshed line.
7. The values shown on the schematic may differ from those in the instrument. If so, either value can be used for replacement purposes.

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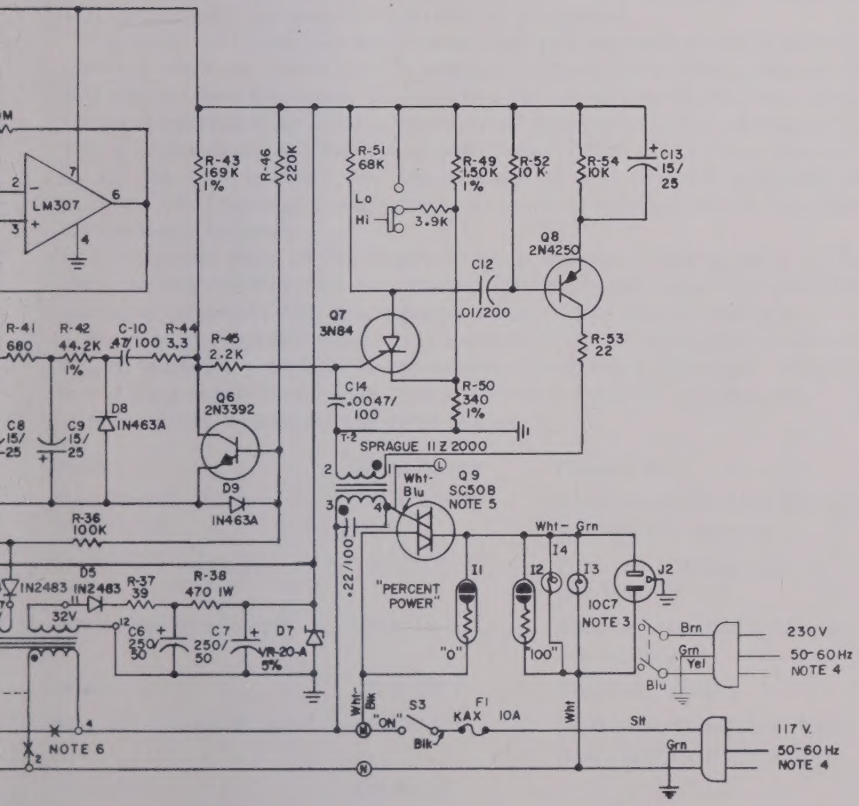

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the system by the heater. Consequently the probe should be located in the path of the heat propagation from the heater to the rest of the system. Agitation, stirring, circulating or other methods of mixing must be employed to attain this end for two principal reasons: (a) to minimize temperature gradients in the medium and (b) to facilitate fast transfer of heat from the heater to the rest of the system.The particular method of heat dispersion is dependent upon the medium to be controlled. Liquids are generally convenient since they offer relatively good heat conductivity and may be easily stirred or agitated.

Generally, very close control will be obtained with minimum overshoot and undershoot when the control point is changed, if the probe is placed close to the downstream from the heater. Placing the probe some distance from the heater results in better average stability despite large changes in the thermal load of the system. It is emphasized that experimental determination of the probe location is by far the best method. The experimental method has the advantage of automatically including consideration of all the parameters of the particular system under question.

The thermal mass of the heater is often the major limiting factor in the response time of the system. For closest control the heater mass must be kept as low as is consistent with safe wattage density in the thermal medium.

The fluid medium also should be considered. Water is the best bath medium, if a good dielectric (insulator) is not needed. Avoid fluids with vapor pressures over 1 psia at the temperature measured. Try to keep the viscosity low.

Some fluids to consider are listed below:

Fluid	**Temp Range**	**Comment**
Dow Corning 200 Silicone Oil	-40 to 40°C	11/2 Centistoke. Hi dielectric. will leak thru any hole
GE SF 97 Silicone Oil	0 to 100°C	20 cs. Hi dielectric. will leak thru any hole
100% Isopropyl Alcohol	-40 to 0°C	Absorbs water condensing on bath surface
Water	10 to 70°C	Best bath medium
H_2O — Isopropyl Alcohol	-20 to 10°C	Methanol is poisonous; Anti-freeze is slimy and reactive.
Freon Mf	-60 to 0°C	
Silicone Oils 50, 100 CS	70 to 200°C	Pick viscosity appropriate to needed flash point ·
Freon — Alcohol blends	Do not use below dew point	Corrodes metals
Chlorinated Hydrocarbons	Do not use	Slightly conductive, toxic attacks most plastics
Methanol, Methanol-denatured Alcohol	Do not use	Toxic!

YSI has been able to routinely achieve millidegree stability in its Metrology Department baths using Model 72 controllers. This has been achieved by using carefully designed baths that provide minimum transmission delay and by giving attention to the above factors. The baths use Dow Corning 200 which is forced to flow laminarly within a 4 liter dewar flask in a toroidal flow pattern. The dielectric fluid allows using bare heating wire for optimum heating transfer and minimum heat storage. A control probe with one second time constant provides rapid feedback to the controller. Line regulation has not proved necessary for our uses, however the possible need for regulation should not be overlooked. Should it prove necessary, we recommend limiting heater wattage to 200 watts and plugging the instrument into a 200 VA-maximum regulator. Because both the bath and Model 72 are somewhat temperature sensitive, room temperature is kept to within ±1°C.

Load Considerations

The size of the heater load on the Model 72 must be determined in the light of the operating conditions of the system. Resistive heating loads may be directly connected to the three way receptacle located on the back panel of the instrument. The 72-117V instrument is designed to deliver 1.1 kilowatt to RESISTIVE loads, the 72-230V instrument 2.2 kilowatts.

Some applications require the use of a low voltage heater. A step down isolation transformer whose power rating is comparable to the heater capacity is recommended for low voltage applications. A stepdown auto transformer, or Variac transformer may be used; however, extreme care must be taken in wiring or a shock hazard may result. For the same reasons, auto transformers are NOT recommended for 230V use.

Not all transformers can be used with the Model 72. Transformers with sufficient inductive reactance will interfere with the triac operation, sometimes resulting in half-wave output. The non-symmetrical output saturates the transformer, causing it to overheat and sometimes self-destruct. The Model 72 has a slide switch on the printed circuit board which tends to minimize this problem. It also limits maximum power to about 50%. To set, push the switch toward the back of the instrument. Interference with triac operation increases with increasing inductive reactance, which is roughly proportional to power rating, design, and quality of the transformer, and matching of load to power capacity of the transformer.

If a transformer must be used on the output of the YSI Model 72, the following are general recommendations: Isolation transformers are preferred over auto transformers. [If an auto transformer is used, wire so line neutral (on 117V circuits) is connected to the heater, to minimize shock hazard]. High quality transformers are preferred over low quality. Match power output of transformer to heater power, i.e., 10 watt output for 10 watt heater.

Additionally, the transformers may have an in-rush current sufficient to blow the power fuse. The fuses supplied with the Model 72 are a special fast acting type designed to protect the triac from damage by current surges. Only KAX-10A fuses manufactured by Bussman Mfg. Division, McGraw Edison

Company, St. Louis 7, Missouri, should be used for replacement. Use of any other fuse invalidates the warranty.

The relative power delivered to the load may be roughly estimated by comparing by relative brightness of the 0% and the 100% indicators on the front panel. If the 100% indicator is at maximum intensity and the 0% indicator is off, 100% power is being delivered to the load. When the two indicators glow at equal brightness the power to the load is 50%. Other percentages may be estimated by similar comparisons. The two indicators are extremely useful in evaluating system performance. Where the thermal losses of the medium to be controlled are unknown a reasonable estimate of the thermal demand may be made by the use of the two indicators. In general, a satisfactory control condition exists if, upon attainment of equilibrium, the power to the load is indicated within 10% and 60% of full power. As was the case with determining probe location, the experimental method of determining the right heater capacity will by far yield the best and quickest results. The percent power indicators should prove very useful in this case.

Bandwidth Adjustments

A change in the bandwidth control setting changes the bridge a.c. supply thereby altering the magnitude of error signal required to effect a certain change in output power. With narrow bandwidths, the temperature change in the control medium required to offset thermal losses is very small. In this case the temperature of the medium is held to a very close tolerance, typically ±0.01°C. A very narrow bandwidth setting demands a good overall system design to achieve control stability.

In general the best bandwidth setting may be determined by experiment. For any particular situation the bandwidth control should be manipulated so that a stable control condition is reached. For maximum accuracy the narrowest possible bandwidth consistent with acceptable stability should be used.

It should be noted that the calibration of the bandwidth control is only nominal, and that variations in absolute bandwidth will be experienced from instrument to instrument and through the temperature range of a particular instrument. Generally the tolerance will be ±50% for the range of 20°C- 90°C, and ±100% for the rest of the range.

Temperature Adjustment

Any control point within the range of 0°C to 120°C may be selected directly in °C from the front panel of the Model 72. The bridge is calibrated for a bandwidth setting of 0,1°C, and a dialing accuracy of ±0.5°C may be expected with this bandwidth. Since the bandwidth control alters the output of the bridge, with wide bandwidth the controlled temperature will differ from the set point, it will be higher than the set point if the power required is less than 50% and lower for greater than 50% power.

To select a desired control temperature, simply rotate the "Temperature Set Point" dials to the desired temperature and note the percent power indicators. If the temperature of the medium to be controlled is below the selected

temperature, 100% power will be indicated by the % indicators, showing that the heater is full on and that the temperature of the medium is rising. As the control point is approached the indicated power will drop to a level required for maintaining the temperature of the medium constant. Important information of the system stability will be observed by observing the indicators when the control point is approached. An initial overshoot after reaching the control point is normal. The behavior of the system should be observed long enough to establish whether the system is oscillatory or stable. If the power output of the controller does not stabilize, but shows evidence of large cyclic variation, the probable cause is that the system is too sensitive. In this case the bandwidth should be increased to obtain smooth and stable operations.

If the power output, on the other hand, indicates large random variations one possible cause may be poor heat transmission from the heater – to the medium – to the probe, and an improvement of the medium mixing or probe location is indicated. Another possible cause is large random variations in the ambient temperature surrounding the controlled medium.

An excellent "feel" for optimizing a certain control situation will in most cases result if the operator familiarizes himself by experimentation.

CALIBRATION

Calibration of the YSI Model 72 is achieved by the use of fixed precision resistors. If there are any questions concerning calibration consult the factory.

If the YSI Model 72 will not deliver more than 50% power to RESISTIVE loads, check to see that the slide switch is toward the front of the instrument. The "Low" position (toward the back) is for use with INDUCTIVE loads only.

GUARANTEE

All YSI products carry a one-year guarantee on workmanship and materials. Damage through accident, misuse, or tampering will be repaired at a nominal charge, if possible.

If you are experiencing difficulty with a YSI product, it may be returned to an authorized YSI dealer or to the YSI Customer Service Department for repair, even if the warranty has expired.

Customer Service Department
Yellow Springs Instrument Co., Inc.
Box 279
Yellow Springs, Ohio 45387
Phone: 513-767-7241

www.manualsplus.com

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